# APPENDIX D

# ENGINE EXHAUST TEMPERATURE STUDY

## I. **Introduction**

This study was conducted to evaluate the applicability of passive verified diesel emission control strategies (DECS) for public and utility vehicles to comply with the proposed regulation.

As of September 2005, the majority of the diesel emission control strategy devices verified to achieve greater than 85 percent reduction in diesel particulate matter (PM) are passive diesel particulate filters (DPF). This primary goal was to determine which type of vehicle would be able to use passive DPF by assessing the engine exhaust temperatures.

Secondarily, staff can use the results to evaluate the feasibility of using newer technology, such as flow through filters (FTF), based on the projected requirements for a minimum engine exhaust temperature. Diesel oxidation catalysts (DOC) are also dependent on engine exhaust temperature for successful and efficient operation, however require much lower temperatures and only one such DOC specifies a temperature requirement criteria.

The success of a passive DPF relies on four main components: $NO_x$ to PM ratio, total PM emissions, vehicle space availability for the passive DPF, and engine exhaust temperature. Post-1991 heavy-duty diesel engines are best for achieving the $NO_x$ to PM ratio. The maximum PM emissions the passive DPF can handle are predicted, in part, by the frequency of filter regeneration, which, in turn, is dictated by the engine exhaust temperature profile. For example, the Johnson Matthey's verified CRT requires engine exhaust temperatures of 260 degrees Celsius for at least 40 percent of the duty cycle (ARB 2002a). The Engelhard's verified DPX requires an average of 225 degrees Celsius engine exhaust temperature with temperatures in excess of 300 degrees Celsius for a minimum of ten percent of the duty cycle (ARB 2002b). Table 1 presents a summary of the requirements from the verified devices available in the corresponding web site (ARB 2005).

The main objective of this study was to gather data on exhaust temperature profiles for various vehicles/equipment types that are typically used by municipalities and utilities. The data collected determined the percent of the public and utility fleet vehicles which have the operational characteristics appropriate for aftertreatment retrofits.

Table 1. DECS Temperature Requirements

| PM Level | Technology Type | PM Reduction | NOx Reduction | | Min. Temp C. | Duration |
|---|---|---|---|---|---|---|
| Level 3 | DPF | 85% | 25% | | 260 | 40% |
| | DPF | 85% | 25% | | 225 | 50%* |
| | DPF | 85% | N/A | | 225 | 50%* |
| | Lean NOx Cat/ DPF | 85% | 25% | | 260 | 25% |
| | DPF | 85% | N/A | | 225 | 50%* |
| | | | | and | 300 | 10% |
| | DPF | 85% | N/A | | 260 | 40% |
| | DPF | 85% | N/A | | 210 | 40% |
| | EGR/DPF | 85% | 40% | | 260 | 40% |
| | DPF | 85% | N/A | | 280 | 25% |
| Level 2 | Flow Through Filter | 50% | N/A | | 300 | 7% |
| | Alternative Fuel | 50% | 15% | | | |
| Level 1 | DOC | 25% | 25% | | | |
| | DOC | 25% | N/A | | | |
| | DOC + crankcase filter | 25% | N/A | | 100<t<550 | |
| | DOC + crankcase filter | 25% | n.a | | | |
| | DOC | 25% | n.a | | | |
| | DOC + crankcase filter | 25% | n.a | | 100<t<550 | |
| | DOC + SCR | 25% | 80% | | 180 | 55% |
| | DOC | 25% | N/A | | | |
| | DOC | 25% | N/A | | | |

*Average calculated as the 50$^{th}$ percentile

## I. Methodology

Public agencies and utilities own and operate a variety of diesel fueled vehicles which are possible candidates for retrofit devices. In order to determine what vehicles are amenable for PM retrofit, staff proposed that the most common vehicle types as determined by the TIAX report (TIAX 2003) be instrumented with dataloggers to determine an average temperature profile for each type. Staff analyzed this engine exhaust temperatures data to determined which percentage of the fleet could possibly use the currently verified passive DPF successfully.

### A. Vehicle Selection and Fleet Composition

The study was conducted from November 2003 to September 2004 with an original targeted population of 59 vehicles from public fleets. The vehicle types included dump, flatbed, service and tractor trucks; as well as specialized vehicles such as boom trucks, aerial lifts, cranes, sewer vactor vehicles and sweepers. In order to determine what vehicles are amenable for PM retrofit, staff used the most common vehicle types as determined by the TIAX report. Table 2 lists the top ten vehicle types that are diesel-fueled and over 14,000 GVWR used by the municipalities.

Table 2. Top Ten Diesel-Fueled Vehicle Types

| Vehicle Type | No. of Vehicles | Percent of Fleet |
|---|---|---|
| Dump Truck | 1,558 | 22% |
| Plow & Spreader Truck | 1,058 | 15% |
| Sweeper | 472 | 7% |
| Cargo Truck | 463 | 7% |
| Tractor Truck | 350 | 5% |
| Sewer Truck | 249 | 4% |
| Service Truck | 238 | 3% |
| Flatbed Truck | 224 | 3% |
| Aerial Lift Truck | 205 | 3% |
| Crane | 153 | 2% |
| Total: | 4,970 | 71% |

The survey also revealed that the activity level for each vehicle type vary greatly based upon the type of municipality or utility. Fleets were selected to be representative of various municipality or utility types.

1. City of Los Angeles,
2. City of Long Beach,
3. City of Pasadena,
4. Los Angeles Department of Water and Power (DWP),
5. County of Los Angeles,
6. California Department of Transportation (CalTrans),
7. US Marine Corps (USMC), and
8. Southern California Edison (SC Edison).

An average of six of the most common vehicle type by municipality or utility were instrumented in each of the types, for a total of 59 vehicles, for a period of time representative of normal operational activity, for at least five days. Data collection took approximately a year. Staff worked with municipality and utility staff to ensure that vehicles were datalogged for periods of actual operation. Table 3 present the vehicles distribution of vehicles selected for the study. For convenience the number of vehicles with useful data is also presented.

Table 3. Vehicles Selected for Instrumentation.

| Vehicle Type | City of LA | City of Long Beach | City of Pasa-dena | DWP[1] | County of LA | Cal Trans[2] | USMC[3] | SC Edison[4] | Total | Vehicles with useful data |
|---|---|---|---|---|---|---|---|---|---|---|
| Dump Truck | 3 | 2 | 4 | 1 | 2 | 4 | 3 | | 19 | 16 |
| Plow & Spreader Truck | | | | | | 3 | | | 3 | 3 |
| Sweeper | 6 | | 3 | 1 | | 2 | | | 12 | 8 |
| Cargo Truck | | | | | | | | | 0 | 0 |
| Tractor Truck | 1 | | | 2 | | | 2 | | 5 | 1 |
| Sewer Truck | 1 | 2 | | | 1 | 2 | | | 6 | 5 |
| Service Truck | | 1 | | | 2 | | | | 3 | 3 |
| Flatbed Truck | | | | 2 | | | | | 2 | 2 |
| Aerial Lift Truck | | 1 | | | 1 | 1 | | 2 | 5 | 5 |
| Crane | | 1 | | 2 | | 1 | | | 4 | 2 |
| Total: | 11 | 7 | 7 | 8 | 6 | 13 | 5 | 2 | 59 | 45 |

1. Los Angeles Department of Water and Power.
2. California Department of Transportation,
3. US Marine Corps, and
4. Southern California Edison.

## B. Equipment: Engine Exhaust Temperature Dataloggers and Vehicle Characteristics

The dataloggers were four DT500 Series DataTakers purchased by the ARB in 2001. They collect engine exhaust temperature in a second by second basis. In addition to the electronic automated logging, ARB staff recorded the basic information on each vehicle on the data collection sheet presented in Figure 1. The 59 vehicles selected to represent the types and engine makes of the fleets are presented in Table 4 as well as their basic information of their engine manufacturer, engine model, vehicle manufacturer, and model year. The data were collected for a minimum of one work week (five days) on each vehicle, with approximately 100,000 seconds worth of data per vehicle. Although staff installed dataloggers on 59 vehicles, the data of only 45 meet the criteria for inclusion in this report.

Figure 1. Vehicle Data Collection Sheet.

| | | | |
|---|---|---|---|
| CONTACT INFORMATION | | Date: | Init: |
| 1. Fleet Contact Name: | | | |
| 2. Fleet Business Name: | | | |
| 3. Fleet Terminal #: | | | |
| 4. Fleet Terminal Address: | | | |
| VEHICLE INFORMATION | | | |
| 5. Vehicle Identification No.: | | | |
| 6. License Plate No.: | | | Comments: |
| 7. Vehicle Type/Model: | | | |
| 8. Vehicle Manufacturer: | | | |
| 9. Vehicle GVWR: | | Pounds | |
| 10. Vehicle Model Year: | | | |
| 11. Estimated mpg: | | Mpg | |
| 12. Current Vehicle Mileage: | | Miles | |
| ENGINE INFORMATION | | | |
| 13. Engine Manufacturer: | | | |
| 14. Engine Model: | | | |
| 15. Engine Model Year: | | | |
| 16. Engine Horsepower: | | hp | |
| 17. Engine Displacement: | | in$^3$/liters | |
| 18. Current Engine Mileage: | | miles/hours | |
| 19. Engine Mileage at Last Rebuild, Repower, Replacement: | | miles/hours | |
| 20. Engine Mileage when Next Expect to Rebuild Engine: | | miles/hours | |
| 21. Fuel Injection: | Yes/No | | |
| 22. Aspiration: | Yes/No | | |
| 23. Transmission: | | | |
| 24. Cycle | Two/four | | |
| 25. Fuel Sulfur Content: | CARB/15 ppm | | |
| 26. Number of teeth on the flywheel: | | | |
| 27. Emission Certification: | | | |
| EXHAUST INFORMATION | | | |
| 28. Exhaust Location: | Up/down | | |
| 29. Exhaust Configuration: | Single/dual | | |
| 30. Exhaust Pipe Diameter: | | mm/inches | |
| 31. Underbody Clearance: | | inches | |
| 32. Currently using DPF? | Yes/No | | |
| OIL CONSUMPTION INFORMATION | | | |
| 33. Current Engine Lubricating Oil Consumption | | Qts/Wk | |
| 34. What is manufacturer's suggested oil consumption? | | _______/_______ | |
| 35. Does engine utilize devices that enable less frequent oil changes? | Yes/No | | |
| 36. How often is crankcase oil replaced with new oil? | | _______/_______ | |
| FUEL DATA | | | |
| 37. Where do you buy your diesel fuel? | | | |
| 38. How frequently do you buy your fuel? | | per | |
| 39. How much do you buy each time? | | Gallons | |
| ARB DATA COLLECTION | | | |
| 40. Smoke opacity test results (attach results strip to this sheet) | 1: | 4: | |
| | 2: | 5: | |
| | 3: | 6: | |
| 40. Does the vehicle have access to power source for active DPF? | YES/NO What: | | |

Table 4. Datalogged Vehicle Description.

| Veh# | Vehicle Type | Agency | Engine Manufacturer | Engine Model | Vehicle Manufacturer | Model Year |
|---|---|---|---|---|---|---|
| 1 | Tractor Truck | LA City | Caterpillar | 3406 | Peterbilt | 1996 |
| 2 | Dump Truck | Long Beach City | Mack | EC6-265 | Mack | 1987 |
| 3 | Dump Truck | LA City | Caterpillar | 3306 | Peterbilt | 1996 |
| 4 | Sweeper | Pasadena | Cummins | ISB-190 | FRHT | 1998 |
| 4A | Sweeper | Pasadena | Cummins | ISB-190 | FRHT | 1998 |
| 5 | Sweeper | LA City | Caterpillar | 3126 | Freightliner Broombear | 2002 |
| 6 | Dump Truck | Long Beach City | Caterpillar | 3306 | Freightliner | 1988 |
| 7 | Sweeper | LA City | Caterpillar | 3126 | 5 Star Broom Bear | 2002 |
| 8 | Dump Truck | LA City | Caterpillar | 3306 | Peterbilt | 1997 |
| 8A | Dump Truck | LA City | Caterpillar | 3306 | Peterbilt | 1997 |
| 9 | Sweeper | LA City | Caterpillar | 3126 | Freightliner | 2002 |
| 10 | Crane | LA DWP | Caterpillar | 3126 | GMC | 1999 |
| 11 | Crane | LA DWP | Caterpillar | 3126 | GMC | 1999 |
| 12 | Crane | Cal Trans | Cummins | DT-466-210 BC | International | 1987 |
| 13 | Sweeper | LA City | Caterpillar | 3126 | 5 Star Broom Bear | 2002 |
| 14 | Dump Truck | USMC | Caterpillar | C-12 | Navistar | 2000 |
| 15 | Dump Truck | USMC | Caterpillar | C-12 | Navistar | 2000 |
| 16 | Dump Truck | Pasadena | Caterpillar | 3116 | GMC | 1997 |
| 17 | Lift Knuckle Boom | Cal Trans | Navistar | E-210 | Navistar | 1991 |
| 18 | Sweeper | Pasadena | Caterpillar | 3116 | GMC | 1997 |
| 19 | Dump Truck | Cal Trans | Caterpillar | 3126 | Freightliner | 2001 |
| 20 | Lift Aerial Boom | LA County Public Works | Navistar | D-210C | Navistar | 1989 |
| 21 | Sweeper | Cal Trans | Cummins | ISD-205 | Elgin Sweeper | 2002 |
| 22 | Dump Truck | Pasadena | Caterpillar | 3116 | GMC | 1997 |
| 23 | Dump Truck | USMC | Navistar | C-12 | Caterpillar | 2001 |
| 24 | Sweeper | Cal Trans | Cummins | ISD-205 | Elgin Sweeper | 2003 |
| 25 | Sewer Vactor | LA County Public Works | Caterpillar | C-10 | International Harvester | 2002 |
| 26 | Sewer Vactor | Long Beach City | Caterpillar | 3116 | GMC | 1998 |
| 27 | Sewer Vactor | Long Beach City | Cummins | 8.3-C | Ford | 1997 |
| 28 | Dump Truck | Pasadena | Caterpillar | 3116 | GMC | 1997 |

Table 4. Datalogged Vehicle Description (continued).

| Veh# | Vehicle Type | Agency | Engine Manufacturer | Engine Model | Vehicle Manufacturer | Model Year |
|---|---|---|---|---|---|---|
| 29 | Dump Truck | Pasadena | Caterpillar | 3116 | GMC | 1997 |
| 30 | Lift Boom Truck | Long Beach City | Caterpillar | 3116 | GMC | 1992 |
| 31 | Service Truck | Long Beach City | Navistar | 7.3 Power-stroke | Ford | 2000 |
| 32 | Crane Boom Truck | Long Beach City | Caterpillar | 3126 | FRHT | 2001 |
| 33 | Dump Truck 10-wheeler | LA County Public Works | Caterpillar | C-15 | FRHT | 2002 |
| 34 | Dump Truck / Tandem Axle | LA County Public Works | Caterpillar | C-15 | FRHT | 2002 |
| 35 | Dump Truck/ 5500-6X4 | LA DWP | Cummins | ISM-400V | International | 2002 |
| 36 | Sweeper Trk | LA DWP | Caterpillar | 3126 | 5 Star-Freightliner | 2002 |
| 37 | Sevice Crew Cab | LA County Public Works | International | Power Stroke Diesel | Ford | 2001 |
| 38 | Sevice Crew Cab | LA County Public Works | Navistar | Power Stroke Diesel | Ford | 2001 |
| 39 | Flatbed Truck | LA DPW | Cummins | ISM-320V | Kenworth/T800B | 2002 |
| 40 | Sewer Vactor | Cal Trans | Caterpillar | C-12 | International | 2001 |
| 41 | Sweeper | LA City | Caterpillar | 3126 | 5 Star-Freightliner | 2003 |
| 42 | Dump Truck | Cal Trans | Cummins | ISM | Volvo | 2001 |
| 43 | Flatbed Truck | LA DPW | Cummins | ISM-320V | Kenworth/T800B | 2002 |
| 44 | Dump Truck | Cal Trans | Cummins | ISM | International | 2001 |
| 45 | Dump Truck | Cal Trans | Cummins | ISM | Volvo | 2001 |
| 46 | Sewer Vactor | LA City | Caterpillar | 3126 | Sterling/Ford | 2002 |
| 47 | Sewer Vactor | Cal Trans | Caterpillar | C-12 | International | 2001 |
| 48 | Sweeper | LA City | Caterpillar | 3126 | Freightliner | 2002 |
| 49 | Lift Aerial Truck | SC Edison | Navistar | DT-466 HT | Navistar | 1995 |
| 50 | Lift Aerial Truck | SC Edison | Navistar | DT-466 HT | Navistar | 1996 |
| 51 | Dump/Plow Trk | Cal Trans | Navistar | DT-466 HT | Navistar | 1992 |
| 52 | Dump/Plow Trk | Cal Trans | Cummins | ISM 370 | Volvo | 2001 |
| 53 | Dump/Plow Trk | Cal Trans | Cummins | ISM 370 | Volvo | 2001 |
| 54 | Tractor Truck | LA DWP | Cummins | NTC-400-BG3 | International | 1985 |
| 55 | Tractor Truck | LA DWP | Cummins | NTC-400-BG3 | International | 1984 |
| 56 | Tractor Truck | USMC | Caterpillar | C-12 | International | 2003 |
| 57 | Tractor Truck | USMC | Caterpillar | C-12 | International | 2003 |

## II. Results and Discussion

### A. Engine Exhaust Temperatures

Engine exhaust temperatures were collected and analyzed for the applicability of mainly two types of passive DPFs or one type of FTF. ARB Staff assessed a range of conditions that the diverse suppliers required for minimum engine exhaust temperatures and frequency distributions. The conditions ranged from temperatures equal or above 210 C for more than 40% to 300 C for more than 10% of the operation of the vehicle's engine or a combination of the conditions. For the case of one DOC the conditions require temperatures between 100 C to 500 C. Table 5 presents the range of condition evaluated. More vehicles were able to meet the engine exhaust temperature requirements of the FTF than either passive DPF.

#### 1. Passive Diesel Particulate Filters and Flow Though Filters

In general, the vehicles experienced low engine exhaust temperatures. About 56 percent of the tested vehicles meet the criteria of a level 3 DPF device that required equal or above 210 C for more than 40% of the time. The criteria for the level 2 FTF device were met by 67% of the tested vehicles. The engine exhaust criteria was for a temperature of 300 C for more than 7% of the time.

##### a. Analysis By Vehicle Type

The results analyzed by vehicle type illustrate which vehicle duty cycles appear to be more severe when compared to the others. For convenience a summary of the results by type, engine manufacturer, and model year is presented in Table 5. This table list eight different temperatures and temperature frequencies criteria reported by the DECS manufacturers from T1 to T7 found in Table 1. The temperature stated has to be reached or surpassed for the percent of the time stated. The control levels are stated at the top of the columns. The column labeled T2&T7 is for a level 3 device that has to meet both temperature and frequency criteria.

In most cases, relative to the DPF, the FTF engine exhaust temperature requirements were easier to meet. With the exception of the sewer vactor vehicles where the FTF requirements were meet at a lower percentage. The pattern showed by the DPF and FTF are presented in Figure 2. Dump/plow and flatbed trucks duty cycles were most amenable to the use of these passive DPFs, followed by sweepers and service trucks with 50% to 67% of the vehicles achieving the regeneration temperatures. Aerial lifts and cranes showed the lowest feasibility to use retrofit devices along with tractor trucks, although there was only one of the later.

Table 5. Summary Results.

| | | Lev. | 3 | 3 | 3 | 3 | 3 | 2 | | 3 | 1 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Required minimum temperatures and frequencies | | | | | | | | | Min |
| | No. | | T1 | T2 | T3 | T4 | T5 | T6 | T7 | | Max |
| | of | C | 210 | 225 | 260 | 260 | 280 | 300 | 300 | T2& | 100 |
| | Veh | % | 40 | 50 | 25 | 40 | 25 | 7 | 10 | T7 | 500 |
| By Vehicle Type | | | | | | | | | | | |
| Dump Truck | 16 | | 56% | 6% | 31% | 6% | 19% | 81% | 56% | 6% | 100% |
| Dump/Plow Truck | 3 | | 100% | 100% | 100% | 33% | 100% | 100% | 100% | 100% | 67% |
| Sweeper | 8 | | 63% | 50% | 63% | 38% | 38% | 63% | 50% | 50% | 100% |
| Tractor Truck | 1 | | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| Sewer Vactor | 5 | | 60% | 0% | 40% | 0% | 20% | 40% | 40% | 0% | 100% |
| Service Truck | 3 | | 67% | 67% | 67% | 33% | 67% | 67% | 67% | 67% | 100% |
| Flatbed Truck | 2 | | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Aerial Lift Truck | 5 | | 20% | 20% | 20% | 20% | 20% | 60% | 60% | 20% | 80% |
| Crane | 2 | | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| By Engine Manufacturer | | | | | | | | | | | |
| Caterpillar | 25 | | 60% | 20% | 40% | 16% | 24% | 64% | 44% | 20% | 100% |
| Cummins | 11 | | 45% | 36% | 55% | 18% | 45% | 64% | 64% | 36% | 100% |
| International | 1 | | 100% | 100% | 100% | 0% | 100% | 100% | 100% | 100% | 100% |
| Navistar | 8 | | 50% | 38% | 38% | 38% | 38% | 75% | 75% | 38% | 75% |
| By Model Year | | | | | | | | | | | |
| 1988-1993 | 5 | | 40% | 40% | 40% | 40% | 40% | 60% | 60% | 40% | 80% |
| 1994-2002 | 38 | | 58% | 26% | 45% | 16% | 32% | 68% | 55% | 26% | 97% |
| 2002-2006 | 2 | | 50% | 50% | 50% | 50% | 50% | 50% | 50% | 50% | 100% |
| All the vehicles | | | | | | | | | | | |
| % meeting conditions | 45 | | 56% | 29% | 44% | 20% | 33% | 67% | 56% | 29% | 96% |

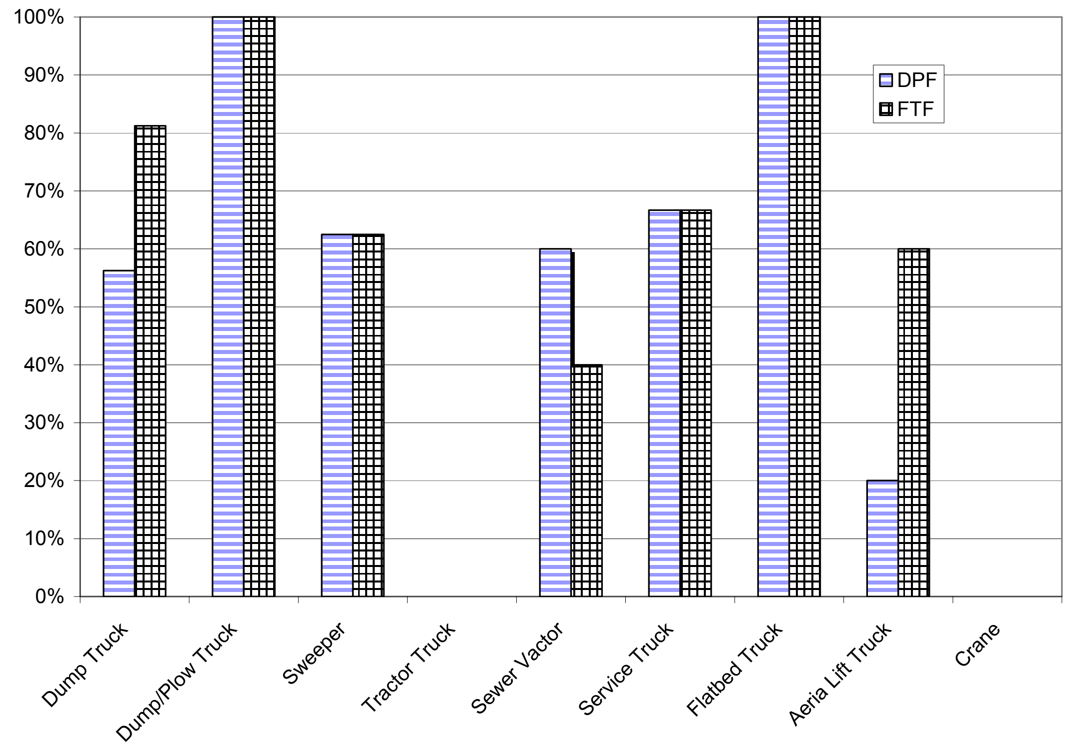


Figure 2. Results by Vehicle Type.

**b. Analysis By Engine Type and By Model Year**

Cummins and Caterpillar engines comprise the greatest percent of test vehicles. Out of 45 vehicles with useful data, 36 had Cummins or Caterpillar engines. Of the Caterpillar engines, 60% achieved the DPF engine exhaust temperature requirements followed by the Cummins engines with 55% and the Navistar engines with 50%. The single International engine achieved almost all the requirements studied with the exception of one of them at 260 C. The majority of the engines achieved the conditions required for the FTF (Table 5).

The majority of the vehicles were in the group 1994 to 2002 which indicated that a DPF could be utilized in 58% of the vehicles, and an FTF could be utilized in 68% of the vehicles. Vehicles from 1988 to 1993 showed similarities for DPF technologies at 40%, whereas the group of two newer sweepers from 2003 was split by half, one achieving all the requirements and the other not. The majority of the vehicles could use the FTF.

The results from the 45 individual vehicles with useful data that meet the specific thresholds of required temperature parameters are presented in Table 6.

## B. Implications for Public and Utility Vehicle Fleet Retrofit Feasibility

The results suggest DPFs may not be able to be used on the full number of vehicles in the verified engine families without significant assistance in increasing the engine exhaust temperature through greater catalysis, using pipe insulation, or locating the DPF closer to the engine. For the FTF technology, the data indicate that this technology may be feasible for a much higher percentage of vehicles, as high as 67 percent. Dump, dump/plow, service, and flatbed trucks, as well as specialized vehicles like sweepers appear to be most suitable to application of either the passive DPF or FTF. Active DPFs where an external heat source is used to regenerate the DPF may be the choice for public and utility vehicles when the exhaust do not generate enough heat to use passive DPFs.

## III. References

ARB. March 15, 2002a. ARB Verification letter to Marty Lassen of Johnson Matthey regarding the CRT diesel particulate filter. http://www.arb.ca.gov/diesel/verifieddevices/ltrs.htm.

ARB. July 23, 2002b. ARB Verification letter to Kevin Hallstrom of Engelhard Corporation regarding the DPX diesel particulate filter. Reference no. RAS-02-23. http://www.arb.ca.gov/diesel/verifieddevices/ltrs.htm.

ARB, Updated August 26, 2005. Diesel Emission Control Strategies Verification, Currently Verified Technologies. http://www.arb.ca.gov/diesel/verdev/currentlyverifiedtech.htm.

TIAX LLC, California Public Fleet Heavy-Duty Vehicle and Equipment Inventory, a report to the California Air Resources Board. March 17, 2003

Table 6. Vehicle Results.

| Vehicle Type | Model Year | Required minimum temperatures and frequencies | | | | | | | | | | Min |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | T0 | T1 | T2 | T3 | T4 | T5 | T6 | T7 | | Max |
| | | C | 180 | 210 | 225 | 260 | 260 | 280 | 300 | 300 | T2& | 100 |
| | | % | 55 | 40 | 50 | 25 | 40 | 25 | 7 | 10 | T7 | 500 |
| Tractor Truck | 1996 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Dump Truck | 1988 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Dump Truck | 1997 | | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| Sweeper | 2002 | | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Crane | 1999 | | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Sweeper | 2002 | | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 |
| Dump Truck | 2000 | | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| Dump Truck | 2000 | | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 |
| Dump Truck | 1997 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Knuckle Boom | 1991 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Sweeper | 1997 | | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 |
| Dump Truck | 2001 | | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 |
| Lift Aerial Boom | 1989 | | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 |
| Sweeper | 2002 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Dump Truck | 1997 | | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 |
| Dump Truck | 2001 | | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 |
| Sweeper | 2003 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Sewer Vactor | 2002 | | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 |
| Sewer Vactor | 1998 | | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Sewer Vactor | 1997 | | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Dump Truck | 1997 | | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| Dump Truck | 1997 | | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 |
| Lift Boom Truck | 1992 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Service Truck | 2000 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Boom Truck | 2001 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Dump Truck | 2002 | | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| Dump Truck | 2002 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Dump Truck | 2002 | | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 |
| Sweeper | 2002 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Sevice Crew Cab | 2001 | | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 |
| Sevice Crew Cab | 2001 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Flatbed Truck | 2002 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Sweeper | 2003 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Dump Truck | 2001 | | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 |
| Flatbed Truck | 2002 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

Table 6. Vehicle Results (continued).

| Vehicle Type | Model Year | Required minimum temperatures and frequencies | T0 | T1 | T2 | T3 | T4 | T5 | T6 | T7 | | Min Max |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | C | 180 | 210 | 225 | 260 | 260 | 280 | 300 | 300 | T2& | 100 |
| | | % | 55 | 40 | 50 | 25 | 40 | 25 | 7 | 10 | T7 | 500 |
| Dump Truck | 2001 | | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 |
| Dump Truck | 2001 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Sewer Vactor | 2002 | | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 |
| Sewer Vactor | 2001 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Sweeper | 2002 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Lift Aerial Truck | 1995 | | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 |
| Lift Aerial Truck | 1996 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| Dump/Plow Trk | 1992 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| Dump/Plow Trk | 2001 | | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 |
| Dump/Plow Trk | 2001 | | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 |
| % meeting conditions | | | 64% | 56% | 29% | 44% | 20% | 33% | 67% | 56% | 29% | 96% |